



# High-Performance Computing, Modeling, and Simulation

Addressing national security challenges through innovative computational solutions on world-class computer resources.

## Computing at Livermore

The goal of high-performance computing (HPC), modeling, and simulation is to transform theories that explain physical phenomenon into models that can reliably predict outcomes, thereby reducing the number of expensive experiments needed to verify predictions or design new products. HPC simulations predict complex physical behavior, while experiments verify the computer simulations with real outcomes.

HPC is a linchpin of the Stockpile Stewardship Program. Scientists at Livermore use HPC to simulate the behavior of matter under extreme conditions of temperature and pressure, which are characteristic of nuclear detonations.

Advanced computing also supports the broader mission needs of the Departments of Energy and its National Nuclear Security Administration and other agencies such as Defense and Homeland Security.

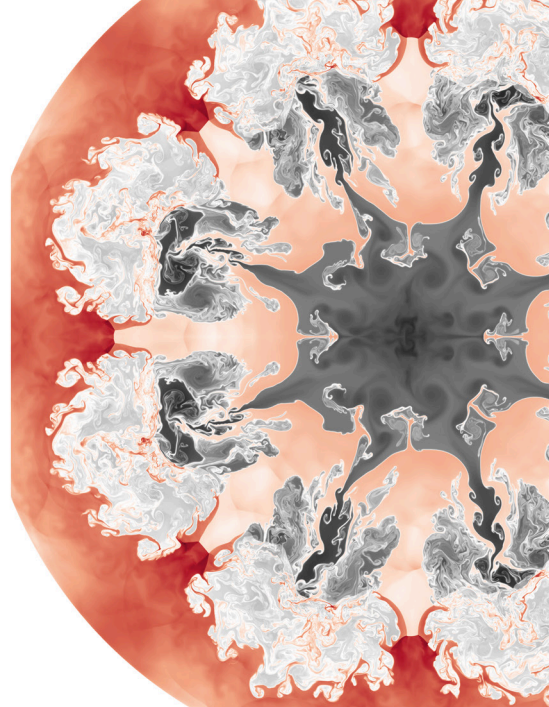
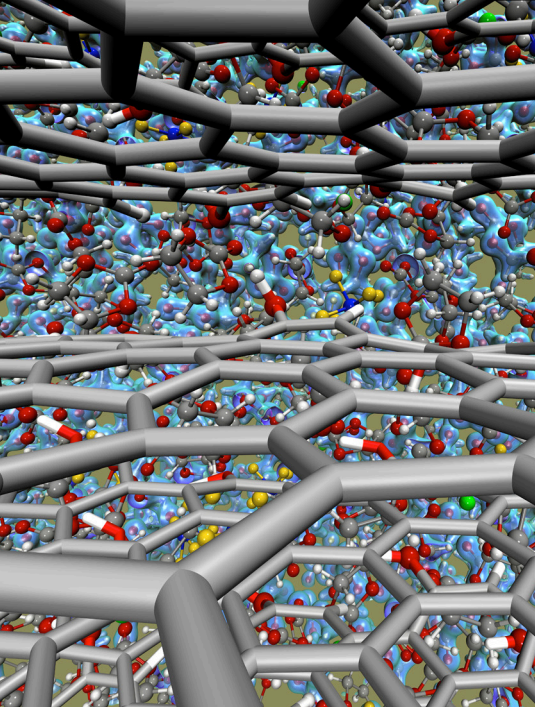
Livermore uses HPC, in cooperation with private sector partners, to solve their technological problems in such areas as semiconductors, steel and glass, and additive manufacturing. In support of its research, the Laboratory operates Livermore Computing (LC), one of the world's most prominent and successful computer centers.

## Accomplishments

Lawrence Livermore is a leader in developing and using HPC to perform its missions in nuclear stockpile stewardship, national security, and basic scientific research. Among its most significant recent accomplishments:

- Annually providing the simulation capability to assure the safety, security, performance, and reliability of the nation's nuclear deterrent during the National Nuclear Security Agency's stockpile assessment process.
- Advancing the nation's progress toward the next generation of powerful computers by helping lead the Department of Energy's (DOE's) Exascale Computing Project and delivering the algorithms, libraries, and applications that are foundational to the success of those systems.
- Partnering with researchers at Livermore and elsewhere to solve science problems, such as:
  - Discerning how the iron cores of planets generate a magnetic field
  - Modeling biological processes to understand cancer tumor growth and streamline drug discovery and approval processes
  - Understanding the life and death of a neutron to provide a window into the subatomic world and gain insight into the way the universe has evolved
- Working with private sector partners to solve their technological problems, resulting in:
  - A next-generation extreme ultraviolet process for making semiconductors
  - More energy-efficient steel making and glass sheet manufacturing processes
  - Improved additive manufacturing processes that result in stronger, more uniform materials





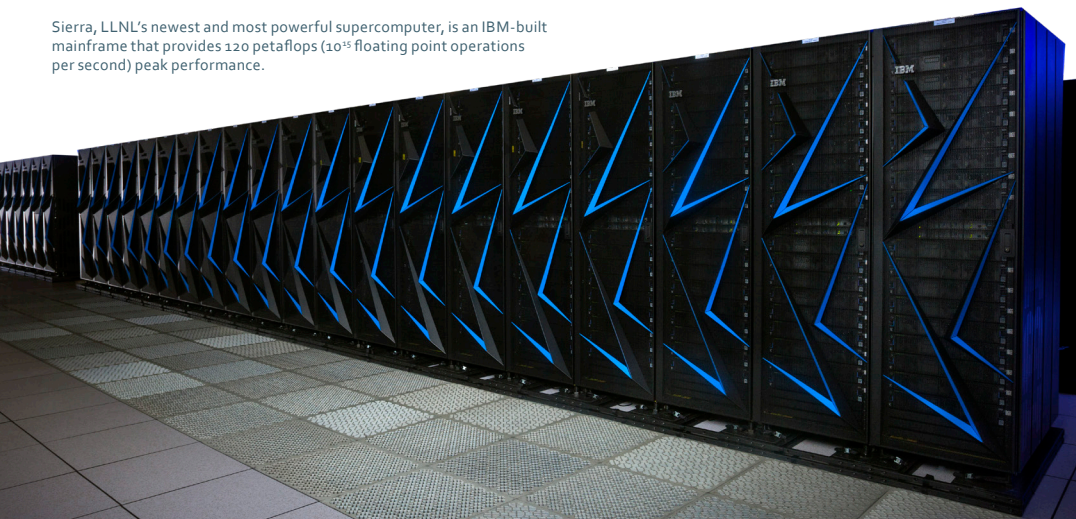
## Scientific Underpinning

HPC at Livermore has developed over many decades in close association with the Laboratory's nuclear weapons mission. Today, HPC is a linchpin of the Stockpile Stewardship Program. Where once nuclear testing provided performance data, now Livermore scientists use HPC to simulate the behavior of matter under extreme conditions of temperature and pressure, which are characteristic of nuclear detonations, as well as the interiors of stars and giant planets.

HPC also supports the broader mission needs of the Departments of Energy and its National Nuclear Security Administration, as well as other agencies such as Defense, Homeland Security, and collaborations with the private sector. Much of the Laboratory's research depends on HPC—it touches all of Livermore's core competencies, including advanced materials, lasers, nuclear and chemical science, biosciences, and the earth and energy sciences.

In support of Livermore's research, the Laboratory operates a major computing center, Livermore Computing (LC), one of the world's most prominent and consistently successful computer centers. Among their many computational assets, LC is home to some of the most powerful computers in the world, several of which are capable of petascale computing ( $10^{15}$  floating point operations per second). These computers use tens of thousands of cores (central processing and graphics processing units) running at the same time—known as parallel processing.

Sierra, LLNL's newest and most powerful supercomputer, is an IBM-built mainframe that provides 120 petaflops ( $10^{15}$  floating point operations per second) peak performance.



## The Future

Developing computing capability to fulfill the Laboratory's missions requires ever more powerful computers, and expertise in computing hardware, software, application codes, and the physical sciences to simulate these phenomena with higher fidelity and more realism.

The Laboratory is home to Sierra, an IBM-built supercomputer that provides 120 petaflops ( $10^{15}$  floating point operations per second) peak performance. Sierra is the "workhorse" for DOE classified stockpile science.

Exascale systems five times more powerful than Sierra are planned for 2023. Livermore is also pushing the frontiers:

- New simulation technologies and algorithms, especially design optimization and decision support.
- Computing beyond exascale: heterogeneous, neural, and quantum architectures.
- Novel paradigms for science enabled by large-scale data analytics, machine learning, and cognitive simulations.

## Principal Sponsorship

- DOE/NSNA

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